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Utah Science



A Publication of the Utah Agricultural
Experiment Station at Utah State University

Volume 71 Issue 1 Spring/Summer 2017

UtahStateUniversity
AGRICULTURAL EXPERIMENT STATION

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A LOOK AT

UtahStateUniversityTM AGRICULTURAL EXPERIMENT STATION



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The Utah Agricultural Experiment Station is part of a network of researchers and facilities at the nation's land-grant universities and is committed to improving agriculture and natural resources for the people of Utah.



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Center for Integrated BioSystems
Intermountain Herbarium
USU Analytical Labs
USU Research Greenhouse Complex
USU Botanical Center
Utah Climate Center
Utah Veterinary Diagnostic Lab
Western Dairy Center

USU-AFFILIATED LABS

- Bee Biology and Systematics Lab
- Forage and Range Research Lab
- Poisonous Plant Research Lab



17 RESEARCH FARMS

CACHE COUNTY

- Animal Science Farm
- Cache County Farm
- Cache Junction Farm
- Caine Dairy Farm
- Cyril Reed Funk Farm
- Evans Farm
- Greenville Farm
- Irrigated Pasture Farm
- Richmond Farm
- Smithfield Farm
- Wellsville Farm
- Wennegren Farm
- West Logan Farm

BOX ELDER COUNTY

- Blue Creek Farm

JUAB COUNTY

- Nephi Dryland Farm

DAVIS COUNTY

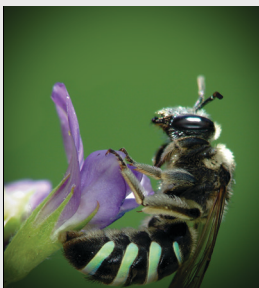
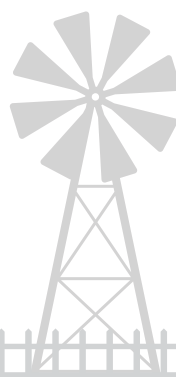
- Kaysville Farm

GARFIELD COUNTY

- Panguitch Utah
- Agriculture
- Experiment Farm



FARM ACREAGE = **2,324**



ON THE COVER

Alkali bee (*Nomia melanderi*) on an alfalfa flower. Some bees of this species have been protected in natural and artificial "bee beds" on private farms, but are among the last remaining populations of these important alfalfa pollinators. Biologists are learning about division of labor among these solitary bees. Photo by James Cane.

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Advances in understanding the genomes of numerous species of animals, and the development of tools to modify them, have accelerated rapidly in the past decade. Utah State University hosted a conference that brought together regulators and scientists from government, industry and academia who use genetically engineered large animals to understand some debilitating diseases.



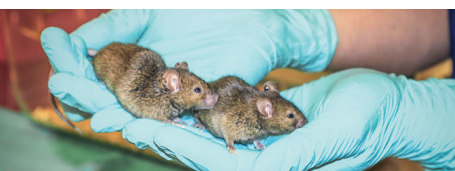
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Utah Agricultural Experiment Station researchers Debra Spielmaker, John Morrey and Terry Messmer are among the recipients of this year's medals honoring the state's leaders in innovation.

SOCIAL VS. SOLITARY BEEES



by Mary-Ann Muffoletto



Clockwise from left: A solitary alkali bee (*Nomia melanderi*) near its nest. Alkali bees are important pollinators of alfalfa. USU researchers and USDA-ARS colleagues harness a female alkali bee and offer a sucrose treatment to test its proboscis response. Photo by James Cane.

Social bees are celebrated for their cooperative industry, but how did their innovative division of labor evolve? A starting point for examining this question may be study of their solitary cousins, say Utah State University biologists.

Karen Kapheim and Makenna Johnson, an undergraduate researcher and recent USU graduate, tested a variation of the reproductive ground plan hypothesis, a long-examined theory in studies of evolution of social bees, in solitary, ground-nesting bees of south central Washington state. They published findings in the Jan. 18, 2017, issue of *Proceedings of the Royal Society B* [DOI: 10.1098/rspb.2016.2406]. The researchers' work was funded by the Utah Agricultural Experiment Station, the USDA-ARS Alfalfa Pollinator Research Initiative and USU.

"This variation of the reproductive ground plan hypothesis suggests division of labor - the ways social bees cooperate to complete all tasks necessary to keep the colony running - evolved from ancestral gene networks that function to align a female's dietary preferences with the nutrients she needs during different phases of her reproductive cycle," says Kapheim, assistant professor in USU's Department of Biology and the USU Ecology Center. "A major limitation in evaluating this hypothesis is that we know almost nothing about the nutritional needs and preferences of solitary bees, which are most similar to social bees' closest ancestor. Yet, solitary bees have no division of labor."

She and Johnson studied alkali bees (*Nomia melanderi*) of Washington's Touchet Valley, an area of robust alfalfa production. As critical alfalfa pollinators, alkali bees are carefully protected in natural and artificially prepared alkaline "bee beds" kept on private farms.

"Some of these beds have been maintained by farmers for five to six generations," Kapheim says. "The Touchet Valley bees are among the last remaining populations of the pollinators, which have succumbed to pesticides in many other areas."



So prized are the bees that the State of Washington posts speed limit signs of 20 miles per hour near bee beds to protect the precious pollinators.

"You feel bad when you're driving through these areas and you hear what might be a 'bee hit,'" says Johnson, a 2016 recipient of a USU College of Science Undergraduate Research Mini-Grant.

The researchers captured bees using traps over nesting holes in the beds for lab study. In the lab, they harnessed individual bees and offered varied sucrose treatments to test each insect's proboscis extension response. They noted the size of a female bee's Dufour's gland, located in the abdomen and playing a number of roles in bee reproduction, was a significant predictor of sucrose response.

Their results suggest, as predicted by the hypothesis, female solitary bees adjust their dietary preferences, when they become reproductively active.

"The Dufour's gland as a predictor of sucrose response in alkali bees was something of a surprise, since this gland, also found in reproductive social bee females, but absent in social drones, is not the reproductive organ typically studied in social bees," Johnson says. "Rather, the ovaries are usually the focus in reproductive studies of honey bees, the research model for social bees."

She and Kapheim think there could be a link between Dufour's gland development, sucrose response and development of division of labor in other species of social bees.

Kapheim says the research suggests independent origins of social behavior evolve via convergent processes, but through lineage-specific pathways.

"Additional research is needed to understand the mechanisms by which division of labor, Dufour's gland development and sucrose response in social bees is related to alkali bees," she says. 🍯

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Top left: Karen Kapheim (left) and Makenna Johnson collect live bee specimens from an Alkali bee bed near an alfalfa field in south central Washington state's Touchet Valley. Photo by James Cane.


Middle left: Biologists Makenna Johnson (left) and Karen Kapheim use microscopy to examine the reproductive organs of a female Alkali bee. The researchers are studying the evolution of division of labor in social bees by testing a variation of the reproductive ground plan hypothesis in solitary bees, which have no division of labor. Photo by Mary-Ann Muffoletto.

Bottom left: Lower speed limits near nesting areas attempt to protect valuable alkali bees. Photo by James Cane.



GETTING TO THE ROOT OF THE PROBLEM

by Shelby Ruud



In terms of plant systems, roots are the under-appreciated, behind-the-scenes hard workers. And despite being vital to a plant's survival, surprising little is understood about how roots interact with the water and soil around them.

This became glaringly apparent to Andrew Kulmatiski in his high school AP biology class when, after spending months learning about leaves and the photosynthesis process, the root system was barely mentioned at all.

"I thought to myself, there's got to be something else happening underground," he said. "At that point I knew I wanted to study soil, roots, and how they relate to each other."

Kulmatiski, a wildland resources assistant professor at Utah State University, said researchers like himself are just starting to develop and use the techniques to understand the interactions that take place underground, but these lines of research have applications in range management, agriculture, food production, wildfire management, air quality and beyond.

A primary function of a plant's root systems is to absorb water. Generally people see the large roots near the surface and assume that's where plants are getting their water. According to Kulmatiski, however, those large roots are just acting as straws to transport water to the rest of the plant. The actual intake of water is performed by thousands of tiny root hairs that are barely visible to the human eye, making it much more difficult to determine exactly where in the soil plants are getting their water from.

While finding the location of root hairs may seem like a small problem, it actually has big implications. Where plants

Top: Assistant Professor Andrew Kulmatiski, student researcher Carlee Coleman and field technician Marina Laforgia at work at the U.S. Sheep Experimental Station, Dubois, Idaho.

Left: Field technicians preparing soil-plant feedback experimental plots. Photos courtesy of Andrew Kulmatiski.



Above: A team of field technicians injecting hydrologic tracers in the bush as part of Assistant Professor Andrew Kulmatiski's research in Kruger National Park, South Africa.

get their water determines how much they grow and how much water they move back into the atmosphere. That, in turn, determines how many clouds are in the sky and how much carbon dioxide and oxygen is in the atmosphere.

"It's really one of the most fundamental processes of life on Earth," Kulmatiski said. "Everything depends on this cycle. But we still don't really know where plants get their water from."

Kulmatiski has developed a technique to get a better understanding of this process. By injecting a tracer made of deuterium, a stable isotope of hydrogen, into the ground at various depths, researchers can figure out where plants are absorbing water from.

Knowing this information could be immensely valuable to farmers and gardeners, according to Kulmatiski.

"From here, we can start to figure out which plants should be able to coexist with each other," he said. "If you have a plant that gets its water

from the surface soils, it should be able to coexist with a plant that gets its water from down deep. By being able to take these measurements of these plants, we can design plant communities or crop systems with plant species that can be working together, growing together and producing more biomass."

Understanding interactions between roots and water becomes even more important as farmers and rangeland managers cope with a changing climate. As the climate warms, the atmosphere can hold more moisture. Precipitation events then become less frequent, but more intense. These intense rainstorms can push water deeper into the soil, which benefits shrubs, sagebrush and other plants with deep rooting patterns, but slows growth of grasses and forbs.

"This could mean less range for grazers and more wildfires," Kulmatiski said. "On the other hand, I wouldn't be surprised if these large precipitation events increase agriculture productivity. There may be

a need to switch to crops or varieties that have a deeper rooting pattern, and our research can help identify the varieties that will do better in these conditions."

But it's not just water that roots are picking up. Bacteria, fungi and other microbial organisms found in the soil can be impossible to see with the naked eye, but can have large impacts on the plants they surround.

Agriculturists have understood this concept for thousands of years. They realized that planting the same crop in one place for a long time means soils begin to accumulate pests and pathogens, so they began rotating crops.

In ecology, researchers have just started to figure out which plants are susceptible to which microbial species, what those microbial species are and how they affect plant growth and interactions with their environment.

"Everything about the way the world works is totally different underground," Kulmatiski said. "There

are thousands of microbial species in every teaspoon of soil, and these are organisms with a constantly changing genetic structure that only live for a few hours. Soils are a cool place to live, but it's hard to know what's going on down there."

Now that researchers agree that soil organisms are important factors in the growth of plants, the next step is to attempt to manage and manipulate those relationships. If researchers can identify which microbial organisms are responsible for which interactions, they can apply that knowledge and control plant-soil interactions for specific goals. Understanding microbial organisms in the soil could be the key to increasing agricultural production, suppressing weeds, increasing plant diversity in conservation areas and adapting plant communities to a changing climate.

Microbial communities also play a role in the way plant communities change over time. When soil is disturbed, whether by burrowing

animals or industrializing humans, the native plants can have a hard time recovering while plants that don't belong can establish and grow.

"We're finding that these nonnative plants can stay for hundreds or thousands of years," Kulmatiski said. "When we disturb soils, we change the subsoil microbial community. Then these nonnative plants begin to grow, and the microbial community has been reduced, so these organisms don't recognize the new plant and don't attack it."

This can be particularly troublesome if the invading plants are harmful to the local ecology. Fortunately, Kulmatiski and other researchers are examining this process and beginning to identify soil pathogens that can control invading plants.

Though Kulmatiski is studying some of the smallest parts of roots and soils, his projects are far from small. In fact, while most researchers study plant-soil interactions in a

greenhouse, Kulmatiski prefers large-scale testing in the field.

"I tend to make projects very big. This can make them difficult to manage, but you get much more reliable results that way," he said. "With ecology, there's so much variability that it's hard to get a big enough sample size to be able to detect a difference, so my approach has always been to get a tremendous sample size."

Results from those experiments are becoming even more important as the world faces a warming climate and a changing human management. As scientists gain a better understanding of how plants survive and thrive, these essential functions that directly effect food supply, oxygen levels and all life on Earth can be monitored and improved for generations to come. ☐



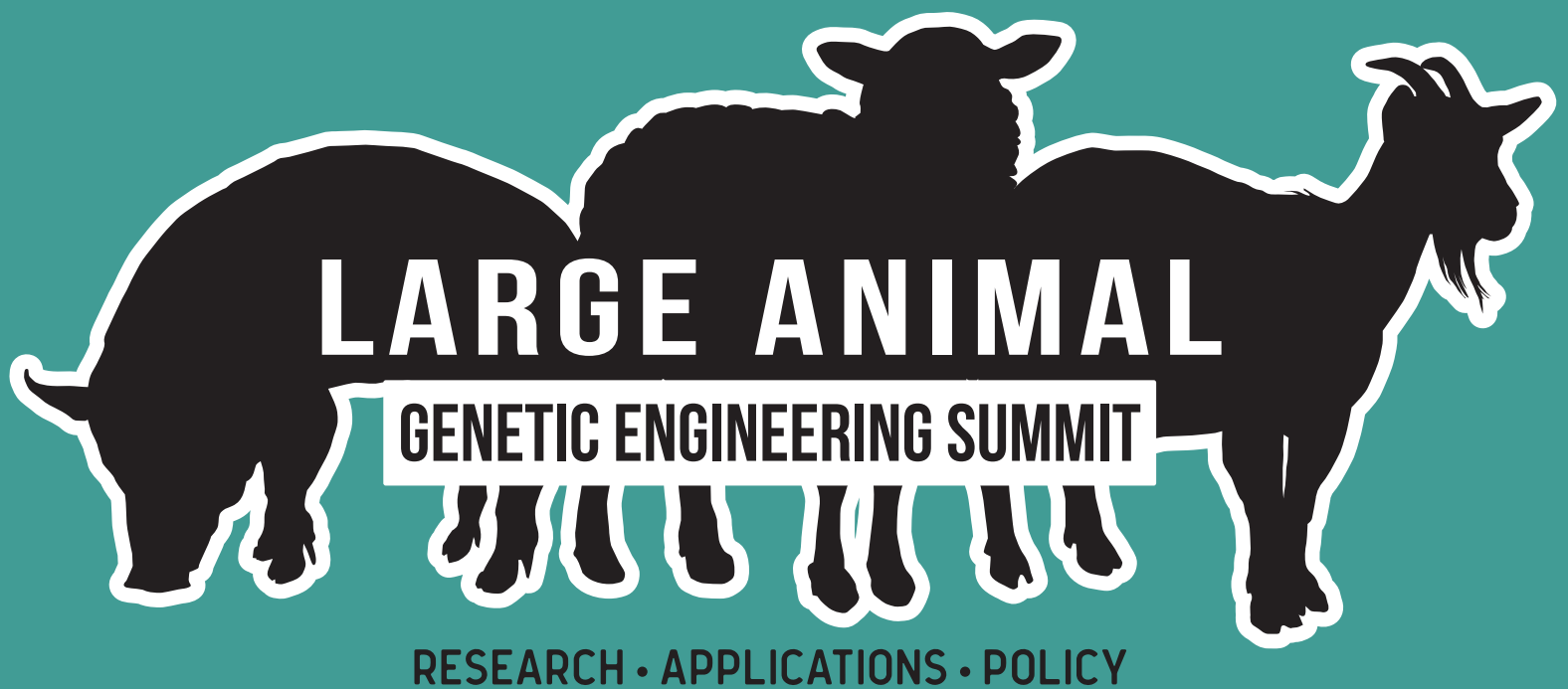
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Below: A shelter provides limited control of precipitation in field research at Hardware Ranch in Hyrum, Utah, where instruments are helping characterize interactions between roots and soil.





LARGE ANIMAL

GENETIC ENGINEERING SUMMIT

RESEARCH • APPLICATIONS • POLICY

by Lynnette Harris

Advances in understanding the genomes of numerous species of animals, and the development of tools to modify them, have accelerated rapidly in the past decade. So rapidly that regulations and research funding haven't always kept pace. Genetically modified animals are being used worldwide as models for understanding many diseases, including Alzheimer's, heart arrhythmia and Parkinson's disease.

Last September, Utah State University's College of Agriculture and Applied Sciences (CAAS) and the Utah Agricultural Experiment Station (UAES) organized a conference that brought together scientists from industry and academia who are developing or using genetically engineered large animals. The Large Animal Genetic Engineering Summit provided a forum for discussing funding mechanisms and regulations with participants from the National Institutes of Health, United States Department of Agriculture and the Federal Drug Administration, and to learn about new approaches to research from scientists from around the world.

The summit focused primarily on work with sheep, goats and pigs. While those may not seem like large animals to most people, they are much larger than the most widely used laboratory animals—mice. There are many benefits to working with larger animal models, for example, their organs are more nearly the size of their human counterparts. But working with large animals presents challenges too, including the fact that



they simply require more specialized facilities and more space than do rodents. That is a challenge land-grant universities like USU, with an established history of working with livestock, are equipped to manage.


Among the presentations at the summit were reports of research related to cardiac function, cancer, cystic fibrosis and diabetes, production of therapeutic antibodies,



improved disease
resistance in animals
and efficient genome editing.

The meeting's organizers,
Associate Professor Irina Polejaeva,
Research Associate Professor and Associate
Director of the UAES, Chris Davies, and Professor and
CAAS Associate Dean for Research DeeVon Bailey, felt that
USU was uniquely positioned to organize a meeting to bring
together scientists and federal officials interested in the
rapidly evolving field of large animal genetic engineering.

"USU is a leader in the development of genetically modified small ruminants for biomedical research," Davies said. "We believe that the development of better animal models for biomedical research will lead to new breakthroughs in the treatment of debilitating diseases. We also recognize the tremendous responsibility that we have as research scientists to understand the consequences of what we are doing and to protect the welfare of the animals that we work with. We want to make sure that our research is conducted in an ethical manner that will ultimately contribute to human and animal health and reduce suffering."

Proceedings from the Large Animal Genetic Engineering Summit are available online at <http://tinyurl.com/LAGE2016proceedings> 

Genetically
engineered animals,
including goats and
pigs, are helping
scientists understand
many debilitating
human diseases.



synthesis:

Research on the Hill 2017

Each year, Research on Capitol Hill celebrates undergraduate research at the state's two research universities: Utah State University and the University of Utah. Among the 28 USU students selected to present posters in the capitol rotunda and meet with state legislators this year were seven who are mentored by Utah Agricultural Experiment Station researchers. The event, organized by USU's Office of Research and Graduate Studies showcases the range of research happening on campus and the experiences young scholars have beyond the classroom.



ASHLI HUNTER

Dietary Supplementation with Tart Cherries for Prevention of Inflammation-Associated Colorectal Cancer in Mice

Mentor

Associate Professor Abby Benninghoff, Animal, Dairy and Veterinary Sciences/USU School of Veterinary Medicine

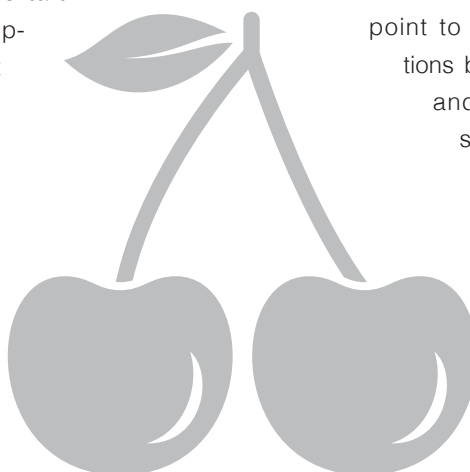
Abstract

The cherry fruit is a nutrient-dense food that contains high amounts of anthocyanins. These bioactive food chemicals have anti-oxidant and anti-cancer properties that contribute to changes in cell signaling pathways involved in inflammation, carcinogenesis and angiogenesis. In this project, we aimed to determine

whether dietary supplementation with tart cherries, prevents colon tumor development in mice consuming a Western diet compared to a prudent diet. We hypothesized dietary supplementation with freeze-dried whole tart cherries would suppress development of colon tumors in a model of colorectal cancer (CRC) incorporating the typical Western diet. A 2x2 factorial design was employed, whereby mice

were fed either the standard AIN93G diet or the total Western diet (TWD), both with and without Montmorency tart cherry powder for a total anthocyanin content of 188 mg/kg diet. The azoxymethane and dextran sodium sulfate model of inflammation-associated CRC was employed. Supplementation with tart cherry powder caused a significant 40% reduction ($p < 0.05$) in tumor incidence in mice fed AIN93G, whereas tart cherries had no effect on tumor incidence in mice fed TWD. Tart cherry powder supplementation did not impact colon tumor number or size. TWD consumption markedly enhanced colitis activity (40-fold increase) and tumor multiplicity (near 6-fold increase) compared to mice fed AIN93G, but tart cherry supplementation did not reduce colitis in mice fed either diet. These observations

point to important interactions between basal diets and dietary bioactive supplements and underscore the need for careful consideration of the role of basal diet in dietary chemoprevention studies in rodents.



Science at Utah State



BOSTON SWAN

Increasing Blue Light From LEDs Reduces Leaf Length in Kale

Mentor

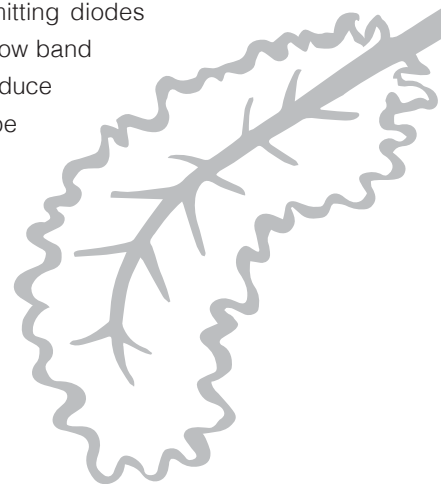
Professor Bruce Bugbee, Plants, Soils and Climate

Abstract

Despite years of research, the effect of light quantity (intensity) and quality (color) on plants remains poorly understood. Light emitting diodes (LEDs) now facilitate this research because of their narrow band wavelength. Blue light (400-500 nm) has been known to reduce leaf expansion and petiole elongation in some crops (Cope and Bugbee, 2013; Cope et al, 2014; Snowden et al, 2016). Kale is one of seven vegetables in the species *Brassica oleracea* and was chosen as a representative for the species because of its nutrient value. The system included 16 chambers; eight chambers at low Photosynthetic photon flux density, (PPFD; 200 $\mu\text{mol m}^{-2}\text{s}^{-1}$) and eight at high PPFD (500 $\mu\text{mol m}^{-2}\text{s}^{-1}$). The

spectral distributions for each chamber are included below.

Whole plant fresh and dry mass decreased slightly with increasing blue light, but the effect was not statistically significant. We also found that leaf length decreased significantly with increasing blue light. Our data indicate that studies should focus on selecting wavelengths of light that enhance cell enlargement and the development of leaf area and radiation capture.



ELEANOR WATSON

The Effect of Behavior and Testosterone Levels on Mating in Garter Snakes

Mentor

Associate Professor Susannah French, Biology

Abstract

In garter snakes, including *Thamnophis sirtalis* and *Thamnophis elegans*, successful mating is dependent, in part, on the ability of males to follow scent trails left by females. This project will investigate how scent trailing behavior influences the ability of male snakes to find a female mate of the same species. Behavior studies will be conducted by presenting male snakes with scents of females of the same species, and with scents from females of a different species. We will observe which scent the males follow. Male snakes' preference will be measured by the number of tongue flicks and seconds spent at each scent. We hypothesize that cyclic changes in hormone levels of these snakes contribute to the laying of species-specific trails by females, and the following of conspecific female trails by males.





GABRIELA JUDD

Wetland Restoration Succeeding Phragmites Control: Informed by Seedling Performance of Alkali Bulrush

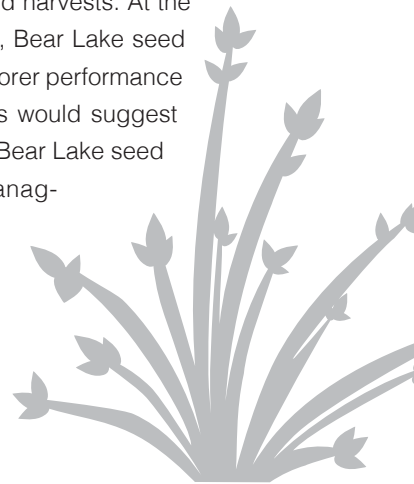
Mentor

Associate Professor Karin Kettenring, Watershed Sciences/Ecology Center

Abstract

Seedling performance of alkali bulrush sourced from different sites: implications for revegetation in Great Salt Lake wetlands. Bulrush (*Schoenoplectus* and *Bolboschoenus* species) are significant in Utah wetlands as they provide critical habitat for millions of migratory birds that utilize the Great Salt Lake. Many agencies in Utah are working to control Phragmites, an invasive species that has outcompeted and replaced bulrushes. Part of this process requires the introduction of native species into wetlands to restore wetland habitat, following Phragmites control, by sowing seeds into areas in need of revegetation. There are many potential seed sources from which to acquire seeds; it is unknown how well plants sourced from various sites will vary in performance. In a greenhouse study, we have grown alkali bulrush (*Bolboschoenus maritimus*) seedlings from five geographically-distant wetland sites across the Intermountain West. We harvested seedlings and evaluated emergence timing, emergence

proportion as well as the following seedling traits critical to restoration outcomes: stem diameter, root length, number of shoots, height of seedlings, and biomass production, at three different time points. Data were analyzed using a one-way ANOVA with seed source as the fixed effect with 5 levels. We found that the Bear Lake seed source had lower seedling emergence than seeds sourced from Clear Lake and Sterling. There were no significant differences among the seed sources for the seedling performance metrics in the first and third harvests. At the second harvest, Bear Lake seed sources had poorer performance overall. Analysis would suggest avoiding using Bear Lake seed for wetland managers. However, there may be no preference between using seeds from the remaining four sites.



SHANNON HEINER

Royal Jelly Diet for In-Vitro Rearing of Bumble Bee Larvae

Mentor

Professor Diane Alston, Biology

Abstract

Royal Jelly Diet for in-vitro Rearing of Bumble Bee Larvae Successful in-vitro rearing of honey bees (*Apis mellifera*) has supported scientific advancements through accelerated laboratory research studies. However, in-vitro rearing has never successfully been conducted for any species of bumble bee larvae. The objective of this research was to test techniques to rear bumble bee larvae in-vitro. With in-vitro rearing, researchers are able to control and manipulate variables such as diet and pesticide exposure, to observe their effects on the study

organisms. Additionally, comparison of experimental data to natural situations can lead to insights about the performance of bumble bees in natural systems. It has been suggested that pollen chemistry may play a role in aspects of bee larval development. For this reason, bumble bee larvae were reared on a pollen-free diet. Honey bee larvae can be reared on a diet of royal jelly, a honey bee secretion that does not contain pollen. As honey bees and bumble bees are closely related, it was thought that bumble bees may be able to survive on a diet of royal jelly. Diets were prepared using a recipe from Standard methods for artificial rearing of *Apis mellifera* larvae (Crailsheim et. al., 2012). Eggs were placed on water agar plates and incubated until they hatched. Larvae were then fed a royal jelly-based diet.

Challenges in successful egg hatch and completion of rearing



larvae for more than 12 days were encountered. The results suggest that bumble bee larvae can be reared in-vitro from eggs on a royal jelly diet, but further challenges remain in determining how to advance their development to mature larvae.





MCKENNA DREW

Green Infrastructure as a Campus Storm Water Management Technique

Mentor

Associate Professor Bo Yang, Landscape Architecture and Environmental Planning

Abstract

The primary impact of urbanization to wa-

ter resources is the increase in impervious surfaces from buildings, parking lots, and transportation corridors. This hardening of an urban watershed can dramatically increase runoff, creating more extreme and more frequent flood events, as well as reducing recharge to groundwater and summer base flows. Urbanization also results in an increase in the types and severity of pollutants. Associated with modified flows is an increase in concentrations and total loads of pollutants, and a decrease in the watershed's natural ability to assimilate these pollutants. Percent ISA (impervious surface area) in small urban watersheds has been suggested as a predictor of cumulative impacts to water quality resulting from urbanization (Chester and Gibbons, 1996). Cumulative ISA greater than 10% appears to put water resources at risk (Mesner, et al, 2015;



Arentsen et al, 2004, Brabec et al, 2002), while watersheds with greater than 25% ISA often have impacted water bodies. Best management practices (BMPs) can mitigate against these impacts. BMPs include landscape features such as grassy swales, retention and detention basins. These are designed to collect and increase infiltration of runoff from parking lots, new subdivisions and other areas of concentrated ISA (Jia et al, 2012).

This research specifically explores how green roofs provide a similar benefit. Precipitation soaks into specially designed vegetated areas on roofs, slowing down and reducing runoff. Green roofs provide the added benefit of reducing temperatures on roof tops, thus mitigating the "heat island" effect seen in many urban areas. The project also includes research on storm water management at USU's Logan main campus through a green infrastructure master plan and educational outreach implementation.

ZACHARY COOPER

High Intensity Ultrasound: A New Way to Replace Partially Hydrogenated Oil

Mentor

Professor Silvana Martini, Nutrition, Dietetics and Food Sciences

Abstract

Interesterified soybean oil was crystallized at 32, 30, 28, and 26 °C with and without high intensity ultrasound (20 kHz). Samples were placed in 1 cm diameter tubes and stored at 5 °C for 48 h. After storage, a 1.3 cm height cylinder was cut from the cylinder and placed in a filter paper (diameter 12.5 cm) at 5 and 25 °C for 24 h. Oil migration was measured as the diameter of the oil diffusing out of the crystalline matrix into the filter paper. Oil migration in samples stored at 25 °C occurred very fast and the diameter of diffused oil exceeded the diameter of the filter paper after 24 h. Oil migration oc-

curred more slowly in samples stored at 5 °C. Results show that samples crystallized in the presence of sonication and stored at 5 °C for oil migration measurements had a significantly lower oil migration compared to the non-sonicated ones. For example, samples crystallized at 32 and 30 °C had diameters of 6.6 ± 0.2 and 8.9 ± 0.6 for samples crystallized without sonication compared to 1.9 ± 0.1 and 1.8 ± 0.1 for samples crystallized in the presence of sonication. The solid fat content of these samples was measured as a function of time and no significant difference was found between sonicated and non-sonicated samples except for in the sample crystallized at 32 °C, which SFC was 2.972 ± 0.3 and 6.584 ± 0.665 % for the non-sonicated and sonicated sample, respectively. This delay in oil migration can be attributed



to differences in the characteristics of the crystalline network formed. Harder and more elastic crystalline networks are obtained in the presence of sonication with significantly smaller crystals. ☐

Photos by Wyatt Traugher

FOOD ON MARS



FOOD ON EARTH

NASA Taps USU Scientists for Space Quest





by Mary-Ann Muffoletto
and Lynnette Harris

Earthlings can live on Mars if they develop self-sufficiency. NASA is betting on a multi-institution team of the best and brightest, including Utah State University scientists, to create the necessary technology and put it in the hands of future Mars pioneers.

Biochemist Lance Seefeldt and botanist Bruce Bugbee are front and center in the \$15 million, 5-year project announced by NASA to initiate the new Space Technology Research Institute, "Center for the Utilization of Biological Engineering in Space" or CUBES.

"It's a really exciting venture," says Seefeldt, professor in USU's Department of Chemistry and Biochemistry and Utah Agricultural Experiment Station (UAES) researcher. "NASA is moving beyond near-Earth orbit projects and investing in technologies to make long-duration space missions possible and sustainable."

Consider the challenge awaiting Mars astronauts, he says.

"It takes at least two years to get supplies from Earth to Mars," Seefeldt says. "That supply line is too slow and costly, so newly arrived Mars explorers are going to have to generate their own food, pharmaceuticals and infrastructure."

Bugbee, UAES researcher and professor in USU's Department of Plants, Soils and Climate, has collaborated with NASA for more than 30 years to study regenerative systems and the effects of microgravity on plants, and notes that every ounce of a rocket's payload drives up the cost of getting it launched so the adage among scientists and engineers is that everything in space is worth its weight in gold.

Left: Before humans can travel and stay on Mars, new high-performance materials and new ways to grow food must be developed and tested.
Illustration courtesy of NASA.



Above: Lance Seefeldt, Bruce Bugbee key players in \$15M, multi-institution project. Photo by Mary-Ann Muffoletto.

Growing food and producing other necessities even on oxygen and nitrogen-rich Earth is no small challenge. It was scarcely a century ago German chemists Haber and Bosch came up with a way to capture nitrogen, on which all living things depend but can't access from the air, and produce commercial-scale quantities of life-sustaining fertilizer. How will Mars farmers accomplish a more complicated task?

"For Mars, we have only carbon dioxide, a little nitrogen and scant surface water to work with," Seefeldt says.

Fortunately, the USU chemist is already reaching beyond Haber-Bosch because, as revolutionary as it was, the 20th century technology relies on fossil fuels and carries a heavy carbon footprint.

"We know we can initiate nitrogen fixation – the process by which nitrogen is converted to ammonia – using bacteria and this is the direction we'll follow to determine how to accomplish this task on Mars," Seefeldt says. "To do this, we need light and though it's more dispersed on

Mars than Earth, it's available."

Once that hurdle is cleared, it's on to food production and who better to tackle this challenge than Bugbee, whose work on all aspects of growing plants in closed systems has helped astronauts and cosmonauts grow plants aboard space shuttles and International Space Station (ISS).

But that work hasn't been with one small and carefully managed crop after another because, nearly 12 years ago, funding for NASA was cut and the agency halted nearly all biological research. Bugbee and his USU colleagues Scott Jones, a soil scientist, and Gail Bingham, emeritus professor of plant science, continued, with Russian collaborators, to gather data and send plants and growth chambers to the ISS on Russian rockets.

As part of those previous pursuits, USU's Crop Physiology Lab bred several varieties of plants especially for characteristics that made them suitable for growing in small chambers. For example, their Apogee Wheat

matures at 23 days, as opposed to a more typical 100+ days, and is just 16 inches tall. A direct spin-off of the research with applications on Earth is that the “super dwarf” wheat is excellent for research in greenhouses on diseases of wheat and treatments because it requires less space than conventional wheat.

“The central challenge is to grow food from recycled wastes in a small, closed system,” Bugbee says. “Exploring Mars means nearly perfect recycling of water, nutrients, gasses and plant parts that aren’t consumed. We’ll start with a recycling, hydroponic system and gradually expand to include Martian soil.”

He adds life on Mars will be sustained by a strictly vegan diet, because animal products are too expensive to produce. Some suggest that long-term space explorers should just live on vitamin pills, dried food and water, but Bugbee cautions there’s plenty we don’t know about the importance of dietary diversity.

“Every day, we eat products from hundreds of plants,” he says. “Most dieticians recommend a diet based on at least a hundred diverse plants; NASA engineers would like to grow only about five plants. The answer is somewhere in between.”

Bugbee also notes that although the effects tending plants has on the human psyche or spirit is not his realm of expertise, astronauts and cosmonauts have noted the boost they get from having green, growing things to focus on while spending months in an otherwise completely artificial environment.

Seefeldt says putting food on the table, whether on Earth or Mars, shouldn’t be taken for granted.

“Here on Earth, in areas such as drought-stricken Africa, where the infrastructure is not yet in place to take advantage of century-old technology, we still face the challenge of producing enough protein to feed hungry people,” he says. “What we learn from feeding people on Mars will advance our efforts on this planet.”

Seefeldt praises the efforts of the multi-institution team, which includes researchers from the University of

California, Berkeley; the University of California, Davis and Stanford University, as well as industrial partners Autodesk and Physical Sciences, Inc., in bringing together a wide ranging group of scientists and skills to tackle some big questions.

“We especially applaud principal investigator Adam Arkin of UC Berkeley, who took this diverse collection of scientists and expertise and gave it one, strong voice,” he says. “This is an exceptional team and its efforts will create amazing opportunities for students at each of these universities.”

“This is an all-star team and the synergistic opportunities are astounding,” Bugbee says. And if I made a list of the top ten USU scientists I would like to collaborate with, Lance would be one of them.”

Both Seefeldt and Bugbee are previous recipients of the D. Wynne Thorne Career Research Award, USU’s highest research honor. They previously collaborated on a U.S. Department of Energy-funded project to produce biofuels from algae. USU’s portion of the NASA grant is approximately \$3.17 million over 5 years. 🟡

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Above: USU’s Crop Physiology Lab, during its decades-long work with NASA, has bred a number of plants specifically for traits that make them suitable for growing in small chambers.

USU LAB MOUSE LIVES TO

132



HUMAN EQUIVALENT YEARS

by Dennis Hinkamp

I first met #6 Red when she was 1,000 days old. That's quite a milestone for a variety of lab mice with an average lifespan of 650 days. Though she moved a little feebly, she was otherwise indistinguishable from other lab mice half her age.

What's the secret of her longevity and youthful appearance? According to Jeffrey Mason, assistant professor with USU's Department of Animal, Dairy and Veterinary Sciences and the School of Veterinary Medicine, the life span of this particular mouse was extended by prolonging her reproductive potential. This meant transferring younger mouse ovaries into her at about 12 months of age; about the time mice reach "menopause."

"Prior to menopause, women benefit from an appreciable health advantage, compared to men of the same age," Mason said. "However, after menopause the risks for disease in women exceed those of both men and pre-menopausal women. Our work may help us someday preserve and extend this premenopausal health advantage."

In more recent experiment in Mason's lab, researchers depleted the germs cells (eggs) from young mouse ovaries before transplanting them to older, post-reproductive mice. Mice that received unaltered new ovaries lived the human equivalent lifespan of 97 years. Mice that received the germ cell-depleted ovaries lived to 112 human equivalent years.

"Number 6 Red kept going to well beyond that to 1,046 days, or 132 human equivalent years," Mason said. "In the current pilot study, ovarian germs cells appeared to be detrimental to the ovary-dependent extension of longevity in our experimental model. Germ cells are those primordial cells that develop into hormone-producing follicles-the female's eggs and if fertilized, they will become the embryos that ultimately produce offspring. In actively cycling females, the germ cells produce estrogen and progesterone. Removing these germ cells significantly decreases the production of these ovarian hormones. Hormone replacement therapy has benefitted millions of postmenopausal women, but it appears that there is more to female health and longevity





Bottom Left: Assistant Professor Jeff Mason with Red #6 climbing his lab coat (far left) and the long-lived mouse in her cage.

Above: Red #6, on the left, at age 1,000 days is barely distinguishable from another of her breed that was just 200 days old. Photos by Dennis Hinkamp.

than just estrogen and progesterone.”

Mason noted that science and society have paid a lot of attention to living longer, but research to extend “health span” has lagged. Just living longer is not necessarily desirable if you are not also healthy. Mason’s experiments also found that ovary transplantation significantly improved mouse cognitive function, kidney function, immune function and body condition so that mice had more lean muscle and less fat.

“When we examined 16-month-old mice with new ovaries their health parameters compared favorably to 6-month-old mice used as the control group,” he said. “This suggests that the age of the ovary is playing an important role in health and longevity.” The researchers are also looking at the possible effects of transplanting select ovarian cells rather than whole ovaries.

“The original dogma was that reproduction was bad for health, but that doesn’t appear to be the case,” he said.

Other studies have demonstrated that diet-restricted mice live longer than those on a normal diet, Mason said. Mice on the low calorie diet stop reproducing because of the dietary restriction. If these restricted mice are returned to a regular diet 6 months later, they have the potential to reproduce at a much older age, when the normally fed mice have already undergone “menopause.” This may contribute to their longer and healthier lives. However, Mason pointed out that it requires severe dietary restriction to produce these results. Many dietary restricted mice lose a third to a half of their body weight. They had extended fertility and lived longer, but there were side effects, including inability to regulate their body temperature and being

significantly more susceptible to immune challenges. The implications for mouse health are clear, but what are the implications for other mammals?

Part of the drive to understand how to induce early reproductive senescence in animals and then restart their fertility later has a lot to do with horses. Owners of active performance horses often do not want their mares cycling during the performance season, but also want them to be able to pass along valuable genetics when the time is right for breeding. There are existing ways to stop or make a mare’s estrous cycle more predictable, but other methods of managing these valuable animals are being studied.

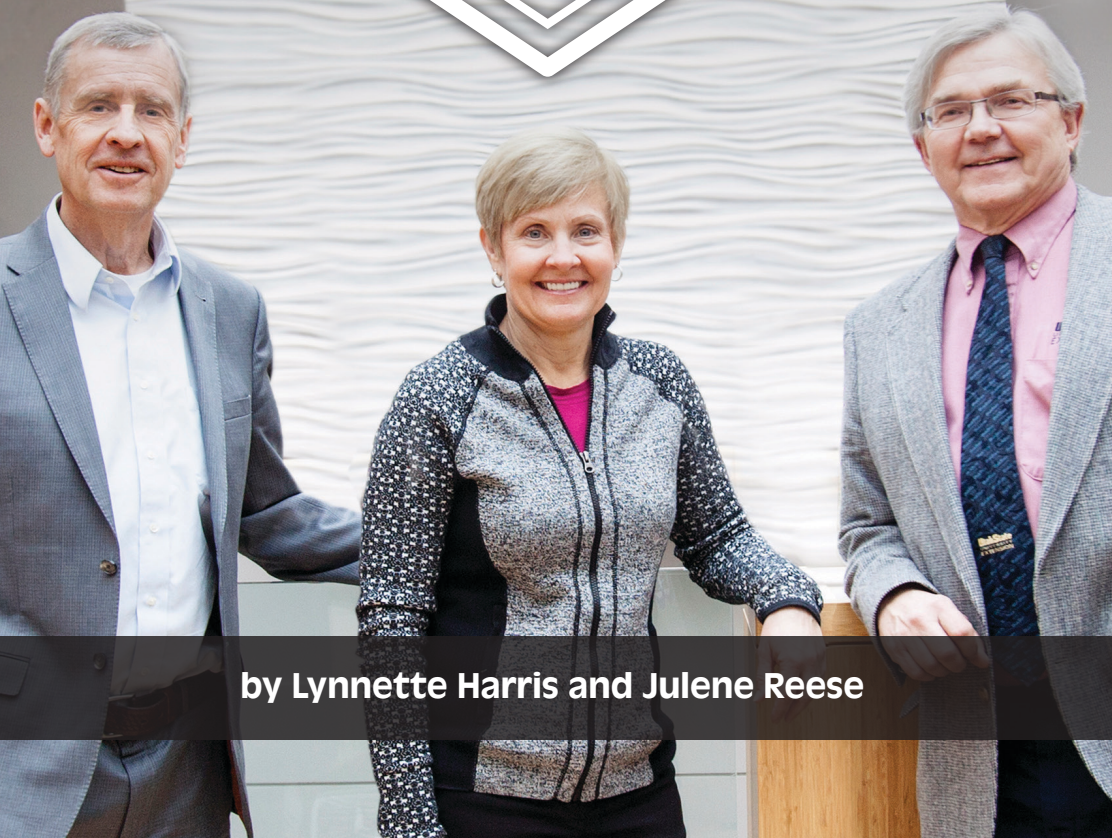
“Our next challenge is figuring out how to induce ovarian quiescence without dietary restriction,” Mason said. “We’re currently exploring a gene therapy approach to do that. Ovary-specific gene therapy will likely be difficult, but in preliminary experiments, we’ve been successful using local gene therapy to alter ovarian cells in live mice.”

Nevertheless, mice are not horses, and horses are not humans. So what about this technology in women?

“Women could potentially benefit from preserving ovarian tissue for re-implantation later in life,” he said. “Women who have undergone serious medical procedures, such as chemotherapy, and that preserved ovarian tissue before the surgery can experience restoration of some reproductive function upon re-implantation of preserved ovarian tissue.”

Applying the science to women may be possible, but science, Mason said, has a long way to go. Mason said that they have no similar experiments to prolong the life of male mice or men underway, yet. □

2017 UTAH GOVERNOR'S MEDALS FOR SCIENCE AND TECHNOLOGY



by Lynnette Harris and Julene Reese

Utah Agricultural Experiment Station researchers Debra Spielmaker, John Morrey and Terry Messmer are among this year's recipients of the Utah Governor's Medal for Excellence in Science and Technology.

"The medal recipients are true leaders in innovation, serving as educators, mentors and influencers statewide," Gov. Gary Herbert said. "I commend the winners for excellence in their fields and for their important work, which will benefit Utah residents for generations."

USU President Noelle Cockett said, "I am very pleased to congratulate these members of our faculty for their outstanding work and achievements. The diversity of disciplines they represent illustrates the excellence we find throughout the university. Also, these individuals showcase USU's commitment to helping people in Utah and beyond through our land grant mission of discovery, learning and outreach."



JOHN MORREY

has built a career understanding and fighting viruses that cause

devastating diseases. He is a research professor in USU's Department of Animal, Dairy and Veterinary Sciences and director of the university's Institute for Antiviral Research, which marked a milestone last year of having acquired more than \$107 million in research funding since the institute's founding in 1977. The institute's core of faculty scientists, technicians and student researchers have used this funding to study viruses, including Zika, West Nile, hantavirus, avian influenza, swine flu, SARS, yellow fever, dengue and others. They also test possible treatments and vaccines that are important in treating diseases worldwide.

Morrey's own research of the past several years has focused on West Nile virus. With funding from the National Institutes of Health, Morrey and his team have made important discoveries about neurological disease caused by West Nile virus. His work has led to world-recognized advances in understanding and treating viral diseases of the brain and liver. His productive career has resulted in 132 peer-reviewed publications, primarily in the areas of virology, neurology, immunology, and therapeutics. In addition, instructional videos on recombinant DNA laboratory techniques produced by Morrey's private venture have been used by scientists worldwide.



DEBRA SPIELMAKER

has been an educator for more than 30 years, starting as a high school and middle school agricultural science teacher. She directed the Utah Agriculture in the Classroom program with USU Extension for 18 years, and provided professional development to over 15,000 K-12 practicing and pre-ser-

vice teachers. She developed a comprehensive, dynamic and nationally recognized Agriculture in the Classroom program. Resources she developed for the Utah K-12 science core curriculum standards use agriculture as a context for learning science related to weather, soil, water, land use, microorganisms, genetics, sustainability, environmental science, and plant and animal science. She is currently director of USDA's National Agriculture in the Classroom program and also a professor teaching and conducting research with practicing teachers enrolled in graduate programs in USU's

School of Applied Sciences, Technology and Education.

Spielmaker has been project director for the USDA-National Institute of Food and Agriculture's (NIFA) Agricultural Literacy program since 2012 and is responsible for all national electronic resources, the Agriculture in the Classroom National Agricultural Curriculum Matrix, professional development, and agricultural literacy research. In 2015, she completed work on the new Utah seventh grade required course, College and Career Awareness. She was responsible for the development of project-based learning instruction integrating STEM and careers as well as teacher professional development.



TERRY MESSMER

has accomplished much during his 25-year career at USU, including the creation of an award-winning conservation program. The USU Extension wildlife specialist and professor in the Department of Wildland Resources, directs the Utah Community-Based Conservation

Program (CBCP), which, working in concert with state and federal partners, has restored more than 500,000 acres of sage-grouse habitat and protected more than 94 percent of the state's sage-grouse populations on 7.5 million acres. The CBCP was recently honored by The Wildlife Society for its contributions to local, state, regional, national and international conservation.

In addition, Messmer was recently honored with two national awards from different organizations recognizing the conservation impacts of the CBCP and his applied research programs. Both awards recognize his leadership and communication abilities and the conservation impacts of his integrated research and Extension programs.

Messmer is noted for his diverse abilities and his passion for the land, stewardship, wildlife and helping those most affected by conservation policies. Whether mentoring graduate students, riding an ATV in the dark to capture sage-grouse, coordinating with the governor's office or working with federal agencies in Washington, D.C., he is motivated by a deep concern for natural resources and the people who depend on them. ☐

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TRANSGENIC GOATS ARE AMONG

the animals that play an important role in biomedical research at Utah State University. The Utah Agricultural Experiment Station hosted a Large Animal Genetic Engineering Summit last fall that brought together researchers and government regulators to share many of the advances being made worldwide with genetically engineered animals. *See page 8.*